

Gravitational waves from the first-order phase transitions

Kian Heshmati

Gravitational waves (GWs) from cosmological phase transitions (PTs) are a promising probe of the early universe. Many theories beyond the Standard Model predict that the early universe experienced a first-order phase transition at the electroweak scale, generating a stochastic gravitational wave background. These signals can provide important insights into the history of the universe, the properties of the early cosmic plasma, and potential new physics beyond the Standard Model. The upcoming space-based observatory, the Laser Interferometer Space Antenna (LISA), set to launch in 2034, is designed to detect these gravitational waves. Finding these signals would allow us to study energy scales much higher than those reachable by particle accelerators.

This study focuses on the gravitational waves generated by sound waves in the early universe's hot plasma, which are the main source of GWs from first-order phase transitions. To accurately describe this process, we use the Sound Shell Model, a theoretical framework that characterizes how sound waves propagate through the plasma and influence the gravitational wave signal. Understanding this mechanism is crucial for predicting the spectral shape and amplitude of the resulting gravitational wave background.

To simulate the gravitational wave power spectrum, we use PTTools, a computational framework for modeling gravitational wave signals from phase transitions. Additionally, we simulate and compare different scenarios—deflagration, detonation, and hybrid models—to study their impact on gravitational wave generation. This approach enhances our understanding of phase transition signals and helps refine predictions for future gravitational wave observations.